Telephony—A Personal View

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Overcoming obstacles in an ever-changing industry

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THE DISTINCTION between mass communications—the press, radio, and television—and the person-to-person communications of the mails and the telephone has been appreciated by pragmatists as well as philosophers. Leon Trotsky wrote of Joseph Stalin's opposition to a proposal for an effective telephone system in the U.S.S.R. Stalin said that no greater instrument for counterrevolution and conspiracy could be imagined. In her book *The Telephone in a Changing World*, Marion May Dilts noted that Adolf Hitler, who fully exploited the mass media, stopped telephone development in Germany by imposing large taxes. The Supreme Court of the United States, which has ruled out special taxes on newspapers as unconstitutional, allows taxes on telephone service. Governments distinguish sharply between person-to-person communications and the few-to-many communications of the press, radio, and television.

Telephony differs from mass communications in providing person-to-person service. It also differs sharply from mass communications in its emphasis on technology. Ithiel de Sola Pool, Professor of Political Science at the Massachusetts Institute of Technology and editor of *The Social Impact of the Telephone*, has written: "Today phone systems are usually dominated by engineers, but in broadcasting organizations, engineers play a rather lowly role. The top positions in commercial systems are held by people from either the programming or marketing side, and in government by civil servants."

In part, the reason for this difference is that the telephone system deals with service, not content. The mass media originate what is to be said; telephone companies provide a means for person-to-person communications.

In part, however, the domination of telephone companies by engineers and the continual push for technological progress arise from the great technological difficulty of providing person-to-person service for many people. Compare radio and television with telephony. If a broadcaster can get a license, he can purchase standard studio and transmitting equipment and go into business. Out there are a lot of people who have bought receiving sets and are responsible for their maintenance. The broadcaster sends the same programs to everyone. He is not concerned about the maintenance of receivers; it is the owner's responsibility to keep the set in order.

In contrast, the telephone user traditionally owned no part of the network but paid for a service. If that service failed, the user put the blame, correctly and promptly, on the purveyor of the service. In the past it was up to the telephone company to restore service quickly, whether the cause of failure lay in the telephone set, in the wires to the home or office, or deep within the complexities of the telephone system. In the United States, those days are gone forever.

The telephone system is the most complicated machine ever constructed by human beings. You can pick up a telephone in New York and dial a number in Los Angeles or Hawaii. The call will be completed without human inter-

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In 1981, W. H. Freeman and Co. published my book *Signals; the Telephone and Beyond*. In 1984, they published a book by Hiroshi Inose and me, titled *Information Technology and Civilization*. This article owes much to both books.

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vention and terminated when you hang up. Machines will prepare the itemized bill that is sent to you.

Telephony has an unusual combination of characteristics. For one thing, the customer's equipment, the telephone set, is an almost negligible fraction of the telephone plant. Most of the cost lies hidden in wires to central offices, in switching, and in transmission between offices. Because of the problem of connecting subscribers, an inherent diseconomy of scale exists when telephone service is provided to many people. The cost of connecting each telephone set directly to every other set would be prohibitive. It is far more efficient to connect each telephone set to a central office and to make the connection between individual wires at the central office.

However, the cost per subscriber must increase with the number of subscribers. The cost increase per additional subscriber is not only the cost of a telephone and the wires to it but also a share in the ever-increasing complexity (and thus cost) of the switching systems that are necessary to connect millions of subscribers. Only high technology combined with economies of scale in research, design, manufacture, and operation can keep the cost of telephony down as service expands.

Another unusual aspect of telephony is that telephone equipment is operated by users who do not have formal training. (In this respect, using a telephone is similar to driving an automobile.) The function of telephone employees is to plan, install, and maintain equipment, and to bill customers.

The telephone system is unusual in another respect. Although the purpose of the telephone system is to serve individual users, maintenance costs for the complicated telephone network (but not for the user's terminal) fall on the telephone company. Without a clue like a burned-out light bulb or a smoking power tool to indicate the problem, there can be no clear distinction in the user's mind among different modes of failure.

The Development and Impact of Telephony

The invention of the telephone was not heralded as the beginning of a social revolution. Indeed, its place in society, if any, was not clear. Would it be used to "broadcast" news to homes and offices? This was tried in Hungary. Would "private lines" interconnect the offices and buildings of particular enterprises?

The wonder is that something as complicated as telephony could become the universal service that it has become in the United States—essential enough and cheap enough to be available to everyone. Indeed, it is still a wonder to me.

Today the telephone is indispensable to our everyday lives as well as to business. We do part of our shopping by telephone. We consult doctors, get information, and arrange meetings over the telephone. We even pour out our hearts to those whom we cannot meet. We use the telephone to call people whom we would not or could not go to see face-to-face, and we sometimes say things over the telephone that we would not say in a person's presence.

Without the telephone, skyscrapers would have been unworkable; the elevators would have been jammed with messengers.

Before the telephone, owners or managers of enterprises had their offices at their plant, where they could supervise operations. With the coming of the telephone, head offices were moved to New York and to other large cities. Without the telephone (and the automobile), the next development—suburban sprawl—would have been impractical.

Initially, it was not at all clear that the invention of the telephone could lead to the cheap and universal service that now exists in the United States. The development of today's American telephone service stemmed from the idea of the telephone as a universal person-to-person service. In 1878, two years after his invention of the telephone, Alexander Graham Bell stated that idea very clearly. In an address to a group of London capitalists associated with the Telephone Company in England, he described switched telephone systems and said, "I believe in the future wires will unite the head offices of the Telephone Company in different cities, and a man in one part of the country may communicate by word of mouth with another in a different place."

Work as well as faith are necessary for the realization of dreams. In 1878, Theodore Vail (then a young mail superintendant for a railroad company) joined the Bell Telephone Company. Although Vail left the company in 1887, he later served as president of its successor, the American Telephone and Telegraph Company (AT&T), from 1907 to 1919.

Vail shared Bell's vision. His favorite slogan was, "One policy, one system, universal service." In 1879 he wrote to one of his staff, "Tell our agents that we have a proposition on foot to connect the different cities for the purpose of personal communication, and in other ways to organize a grand telephone system."

Early telephone rates were not cheap. In New York City in 1896, phone service cost $20.00 a month and the average monthly income of a worker was $38.50. The Bell Telephone Company tried various expedients in an effort to make telephone service generally available. Among the expedients were metered service and the pay phone, which was first introduced in Springfield, MA, in 1883. In the end it was through science and technology that the telephone became a universal service.

Technology and Telephony

From the start, the various Bell companies undertook the assiduous pursuit of technical advances. Their pursuit of science, technology, and invention led in 1925 to the formation of the Bell Telephone Laboratories.

The role of rapid technical progress in telephone service is largely hidden from the everyday user of the telephone—that seemingly simple and inexpensive device with which elaborate data services find it hard to compete. Superficially, telephony seems to change slowly. Such innovations as new types of phones, automatic switching, transoceanic service, direct distance dialing, wide-area telephone service (WATS), and new forms of private branch exchange (PBX) service, including direct in-dialing, have been spaced years apart. The same coaxial cables and microwave systems that are used for long-distance telephone transmission are also used for transmission of radio and television signals by the various networks. This service is little noted by the average telephone user.

Internally, the telephone plant changes rapidly. Provision of an ever-more extensive and complicated service in the face of increased costs of labor and materials has led to a continual search for new materials, new devices, new

techniques, and new methods. Plastics have replaced the wood, metal, and hard rubber of old telephone sets and the expensive lead of cable sheathing. The first submarine telephone cables looked much like telegraph cables. In the newest cables the steel used for strength is in the center of the cable, not on the outside. In a few years we will have transoceanic cables in which lightwave signals travel through transparent fibers. Materials have come to include highly purified semiconductors for integrated circuits and light-emitting diodes and lasers, artificial magnetic materials, artificial quartz for frequency-selective networks, and fibers for optical communications.

Techniques have advanced from transmission on single wires with a ground return (using the earth as a second wire) to transmission on pairs of overhead wires, to transmission on pairs of wires in a cable with loading coils to decrease loss, to amplification with vacuum tubes, to putting many conversations on one pair of wires by frequency-division multiplexing (and later by time-division multiplexing), to transmitting thousands of conversations on coaxial cables, to use of microwave radio for countrywide telephony and television, to transmission by communications satellites, to use of optical fibers.

Amplification and control have progressed from vacuum tubes and relays to transistors and integrated circuits which are smaller and cost less to produce and operate. Switching has progressed from manual switching by telephone operators to "step-by-step," in which control is spread throughout the switching network, to "common-control" systems (such as the crossbar system) which can handle more-complicated types of calls, to computer-controlled switches, to all-electronic switching in which all signals—voice, data, and graphic—are digital.

As a by-product, or product of telephone science and technology, the telephone network has provided facilities for the transmission of television and data. But the technological challenge in providing universal telephone service has been unique in that it has involved integration of all sorts of new technologies into a stable and reliable system. Technological advances have also been the means of reducing the capital costs of universal service.

Telephony Here and There

It is instructive to ask: How universal is telephony in the world?

Telephone usage is very high in the United States, Canada, and Sweden. It is not surprising that usage is similar in those countries. All three have a high GNP and very good telephone service. We should note also that these have been the only countries to have telephone systems that own manufacturing facilities as well as research and operating facilities. Telephony plays a considerably smaller part in the lives of people in other advanced countries, such as the United Kingdom, West Germany, the Netherlands, Israel, and France. In France, it was difficult in the past to get a telephone, to get a dial tone, or the called party even if one had a phone. The French have remedied these faults, and usage is rising. Telephone service in Italy has also been poor.

There may be reasons other than quality of service that explain why the number of calls per person is low in such nations as Switzerland, West Germany, and The Netherlands. Partly, the figure may reflect a lack of aggressive promotion of service. However, it may also be due to problems of language. Teletypewriter service for business purposes is much more common in continental Europe that it is in the United States. Many people who have an adequate reading knowledge of another language are not able to communicate satisfactorily in that language over the telephone. Perhaps the reliance on text in business carries over into private life. But that is mere speculation. Whatever the causes, telephony does not play as prominent a part in the lives of many other advanced nations as it does in our own.

Could the lesser role of telephony also be related to the way that research and development have been carried out in those countries and to the way in which service has been supplied? Let us review the matter. There are several ways in which telephone systems can be operated.

- Some national telephone systems have been operated by a private organization such as the International Telephone and Telegraph Company (IT&T), either directly or under contract for the national government. The telephone systems of Spain and of several South American countries were once operated by IT&T. Because of growing nationalism and growing "governmentalism," those systems have been nationalized as a matter of political policy.
- Some telephone systems are operated as departments of the government, as the United States Postal Service used to be. Revenues go into the treasury. Both expenses and capital needs are met (or not met) through legislative appropriations.
- A telephone system may be operated as a public corporation, as it is in Japan and, more recently, in Britain, with public financing and financing through the sale of bonds. Sometimes there is a separate organization that handles international traffic.
- A telephone system may be operated by one or more private companies, as it is in the United States and Canada. (In Canada, international traffic is carried by a government agency.) Private companies are always regulated, and of course they pay taxes. In the United States, federal, state, and local taxes are a large item of expense, second only to labor. Bell System taxes have been about 22% of operating expenses. Because of deferred taxes (accelerated depreciation) and investment tax credits, however, the taxes actually paid are nearer to 14% of total operating expenses. The figure does not include the local sales taxes and federal excise taxes that are levied on telephone users; those taxes, for which the telephone companies serve as collection agencies, total about $2 billion. All such taxes should be taken into account in comparing private operation with government operation.

Whatever the nature of the telephone system, it primarily supplies a technological service. The system always faces a financial challenge, however, in supplying the service.

When a telephone system is operated by a government department or administration and revenues go directly into the treasury, all the money for operating expenses, expansion of plant, and research and development must come through legislative appropriation. Money for telephony commonly comes at the bottom of the list in legislative interest and enthusiasm. Communication is less pressing

than defense, pensions, welfare, or health care. Telephone service is starved for decades until it is so bad it scarcely seems to merit support.

The public corporation is an attempt to solve the problem of support. The telephone company is allowed to retain its revenues and may borrow money by selling bonds. Sometimes, however, it is difficult to sell bonds. The Nippon Telegraph & Telephone Public Corporation has ingeniously insisted that new subscribers buy bonds to cover the capital cost the company incurs in serving them. Some public corporations, like the United States Postal Service, do poorly because they struggle with the consequences of many years of bad practices and policies that occurred during operation as a government department. Past mischief seems almost irremediable.

Private telephone companies retain earnings and sell bonds and stocks when they can. The total Bell System construction expense in 1980 was about $17.3 billion. Of the total amount, some came from depreciation, some from tax deferrals, some from investment tax credits, and some from retained earnings. About $7 billion had to be raised through the sale of stock or by borrowing. That amount seems small compared with a GNP of over $2000 billion or AT&T's gross operating revenues of about $50 billion. Seven billion dollars, however, is a very large amount to raise in competition with borrowing by government and industry and with investment in industry. Few other industries, if indeed any, must reinvest at the annual rate of nearly 35% of operating revenues ($17.3 billion of $50 billion).

Whatever their nature, telephone companies or administrations have difficult financial problems. But adequate money is not a sufficient condition for success. The success or failure of a telephone company or administration lies in its ability to meet, through research and technical ingenuity, the challenge of the ballooning capital cost of telephony brought about by increasing volume of service, increasing costs of materials and labor, and the provision of new communications services.

Modes of Research and Development

How do various sorts of telephone systems cope with technological change? The challenge is easiest for small systems, whether they are independent companies in the United States or companies or administrations in small independent nations. Small companies or administrations cannot afford extensive research and development. They buy, from various entrepreneurs, good modern equipment that has been developed for a larger market. A certain amount of engineering is necessary to fit the equipment to particular needs, but that is far simpler than creating new technology and embodying it in new systems. In essence, small telephone companies or administrations exploit the state of the international communications art without adding to it. That objective can be carried out very well, but some small companies or administrations spend too little on equipment and give poor service.

All national telephone companies or administrations have research and development laboratories of some sort, but all companies except the Bell System (in the past), Bell Canada, and the Swedish telephone administration have relied largely on outside suppliers. Thus, in general, there is difficulty in relating the problems, ideas, and proposals of telephone administrations to the actual production of telephone equipment. Further, the suppliers themselves have research laboratories, and those in the telephone administration's laboratories may not have access to the real state of the art as understood by the suppliers.

These issues are usually approached through what would be regarded in the United States as a collusive collaboration between the telephone administration or public company and several chosen suppliers. The telephone laboratory itself develops either a prototype system or components for such a system. Because the laboratory (except in Sweden) has no manufacturing facilities, the system or the components are manufactured elsewhere.

The telephone administration or company or its laboratory also supports the development of prototype systems by one, or preferably more than one, supplier. By keeping in close touch during the developmental work, the telephone company or administration keeps reasonably informed concerning current technology and practical problems, and the suppliers are kept informed concerning the telephone system's problems and goals. Bridging the gaps between research, development, manufacture, and service, however, is very difficult.

For a long time in the United States, the creation and application of new technology in telephony was pursued quite differently. The American Telephone and Telegraph Company owned the telephone operating companies and the Western Electric Company, which manufactured much of the telephone equipment used by the Bell operating companies (much of it purchased from other suppliers). AT&T also provided long-distance transmission for Bell companies and independents. Together, AT&T and Western Electric owned Bell Laboratories. AT&T, the operating companies, Western Electric, and Bell Laboratories constituted the Bell System.

The work of the majority of Bell Laboratories employees was the development, right up to drawings for manufacture, of systems and devices to be manufactured by Western Electric, and the systems engineering necessary for the development of such systems and devices. The development work was done at Bell Laboratories rather than at Western Electric for two reasons: (1) to give the operating companies that would use the equipment more influence over the features and performance of the systems, and (2) to provide more stable support to exploratory development than that afforded by manufacture. The sales of Western Electric, like those of other manufacturing companies, change much more drastically through the economic cycle than do the revenues derived from the telephone service.

While Bell Laboratories derived support from Western Electric for specific development projects, it also received support for longer-term exploratory and research work from the telephone operating companies, through AT&T. Thus, support from operating revenues gave Bell Laboratories stability for long-range research, and design for manufacture by Western Electric kept Bell Laboratories in touch with reality.

The strength of research at Bell Laboratories derived its support from relatively stable sources: operating revenues; its close association with development, manufacture, and operation; and an overall Bell management which appreciated the benefits of science and technology.

In spite of the importance of the research done at Bell Laboratories, most of the employees were not research

workers but developers of devices and systems. Of the more than 19600 Bell Laboratories employees (around 1980), only slightly more than 1425 were in research departments. Their work was supported almost wholly by funds derived from the telephone operating companies.

We have seen that telephone companies or administrations and their operations differ greatly in different countries. What can we say of their effectiveness? It is generally acknowledged in the rest of the world, and sometimes in the United States, that American telephony, and communications in general, has led in research, innovation, development, and manufacture, and in excellence of service, including installation, maintenance, and operation. In spite of a huge tax burden and high wages, the price of American telephone service is less than that of any comparable service abroad.

Is Telephony Obsolete?

The "horse and buggy" is obsolete; transportation is not obsolete. Even if person-to-person communications survives, telephony as we have known it might become obsolete.

I have been fortunate to live through a time of fantastic progress and fascinating changes in electrical communications. When I was young, different information technologies served different purposes: printing served text, and so did the mechanical typewriter and telegraphy; photography served pictures and movies; the mechanical phonograph served musical reproduction; the telephone served speech transmission.

Today, all modes of storage, reproduction, switching, and transmission of information are served by one digital electronic art, an art of transistors and integrated circuits. All information operations are coming to depend on on-off pulses that can represent text, sounds (PCM in telephone transmission and compact disc recordings), pictures (in facsimile and in some television), or control signals—in the computers, old and new, that switch telephone and data signals automatically, in the computers that do mathematical calculations, and in the computer systems that edit and format text and reproduce it on paper, sometimes at a great distance.

Today, digital signals travel over land and sea in entirely new ways, via communications satellites and as lightwave signals through transparent fibers so clear that a mere half of the signal power is lost in each two miles of travel. These new technologies are applicable to voice transmission. They are also applicable to the distribution of cable TV. Indeed, it is conservative rather than visionary to envisage a time when optical fibers will run past a majority of homes and offices in the United States and provide multitudinous channels for cable TV.

And what else? Adding digital voice channels to and from the homes passed by such cables would require only a small increment of capacity. And cheap, foolproof integrated circuits could easily provide digital multiplex voice transmission and digital switching. In such a world, what of the expensive subscriber loop or access line that has linked the telephone set to the switch at the central office? That expensive link will be obsolete.

Our analog voice transmission to and from the central office will be obsolete, too. It will be replaced by cheaper digital transmission that can be used interchangeably for voice, text, and graphics—or for all three at once.

Telephony, in the sense that we have known it, will become obsolete, and so will all companies and organizations that are limited to what we now think of as telephone service.

Voice transmission will not become obsolete. But what we will need, and can have if laws and regulations allow, is some easy-to-order-from agency that provides all that telephony now does and many options for voice, text, and graphic communications. Not everyone needs all options, but anyone should have satisfactory access to whatever options he wants. All must work together, providing one universal service within the nation, and, we hope, within one world.

Will we of the United States have such a service? Will Japan? Will France? Will Sweden? Who will?

That depends on freedom to use new technology toward rational, attractive ends. The technology will be available, but the freedom to use it, the license to cooperate in its use, may not. Reaping the advantages of technology depends on will, organization, and government policies.

The governments of our world are preoccupied with very real hostilities, existing and impending, which may mean life or death to the governed. They face tremendous and sometimes tragic problems that arise through unexpected and ill-understood technological change, internal to the country or external. Mostly, they have been poor at fostering the sort of cooperative endeavor that can best profit their citizens and the world in realizing the benefits of complex technologies.

Technological progress can be enormously fast and its benefits enormously great and powerful. Today's information technology allows a diverse and yet unified information service for all modes of information. Such service could be as easily and universally available, as unified and easy to operate, as telephony has been in some fortunate nations. I see the problem of providing such service, and, indeed, the problem of fostering the effective use of other advanced technologies, not as a technical problem. Rather, the problem has become one of organization and government policy.

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